INTERMOUNTAIN STATION
Central Reference File
No. 0.73

APPLIED FORESTRY NOTES

NORTHERN ROCKY MOUNTAIN
FOREST AND RANGE EXPERIMENT STATION

FOREST SERVICE
RECEIVED
APR 29 1937
RESEARCH
INTERMOUNTAIN

No. 80 Missoula, Montana April, 1937

VARIATIONS OF SOME FIRE DANGER FACTORS WITH ALTITUDE, ASPECT, AND TIME OF DAY.

By G. L. Hayes, Junior Forester.

When a fire dispatcher receives the definite location and estimated perimeter of a new fire there are several things which he must consider before deciding how many men to send. Two outstanding factors are rate at which the fire will spread and resistance it will offer to control. Resistance to control can be approximated from the forest fuel type map which also shows rate of spread if the day is fairly bad, or class 5 in character. It does not give rate of spread for other danger classes.

Variations in wind, fuel moisture, or humidity may be so great, even within the limits of a class 5 day, that rate of spread will not be as indicated by the fuel type map. Efficient dispatching, therefore, requires information concerning each of these factors and the resultant class of fire danger at the spot where the fire is located.

About 100 inflammability stations in Region One furnish adequate data for determining 5:00 P.M. fire danger for the immediate vicinity of each station. The majority of these stations are located at low elevations with the remainder at lookouts of moderate to high elevation. In between these altitudes is a poorly sampled zone which includes a goodly share of the area of a Forest. The dispatcher often needs to know the status of danger factors and the class of fire danger at any spot intermediate between these high and low elevation stations; perhaps on a hot, dry, south slope; perhaps on a cool, moist, north slope.

Good dispatching also requires a knowledge of the variations of the factors of danger throughout the day and night at any site. If fire danger resulting from all factors is consistently worse, day and night, in one zone than another, more men will be needed for fire control than if relief in the form of lower wind velocities or higher fuel moistures can normally be expected. Consequently, normal differences in fire danger class and in individual danger factors at different hours of the day or night must be known by altitude and aspect if the fire dispatcher is to "calculate the probabilities" most dependably.

To determine how some fire danger factors vary with time of day, with altitude and with aspect, their measurement was started in 1934 by use of continuously recording instruments at the Priest River Experiment Station in northern Idaho. Stations were located in pairs on north and south facing slopes at 2300, 3800, and 5500 feet elevation. Each station is about 100 feet below the top of a ridge which rises from west to east. All instruments are located in natural or small artificial clearings in the Forest. An additional pair of stations is located in the valley bottom at the foot of the ridge. One is in the open, fully exposed to sun and wind, while the other is partially protected by a forest canopy which has been cut to about one half of full forest density.

Although this study has been under way during only two seasons it has already shown that the factors of fire danger differ significantly by hour of day, by altitude, and even by aspects barely separated by a ridgetop. Marked variations have been found in the class of fire danger resulting from the several factors which control fire behavior. The data shown here represent the median, or typical day of August, 1936. August is chosen because the maximum differences between sites occur in this month. Only the salient features can be presented in this paper. More detail will be presented in later articles.

Temperature

Variations in temperature by hour of day and by altitude on south facing slopes for the month of August, 1936, are presented in figure 1-A. The outstanding features of this figure are:

1. The great diurnal change in temperature in the valley bottom and the slight change at high altitudes. Conditions at night are, therefore, favorable for fire control in the valley bottom but less favorable on the mountain top.

2. The presence of an intermediate altitudinal zone which is practically as hot during the day as it is in the valley bottom, but which is warmer at night than either the valley bottom or the higher slopes above.

3. The slight altitudinal difference in temperature by day compared with the great difference at night. This shows that factors of fire danger are generally similar at different altitudes in the day time but become more diverse at night.

Humidity

Variations of relative humidity are shown by figure 1-B, likewise for south slopes. The outstanding features of this chart are:

1. The great diurnal fluctuation in relative humidity on the valley floor and the slight variation on the mountain top, corresponding to the temperature changes in figure 1-A.

2. The presence of an intermediate zone which remains dangerously dry at night. In this zone, for almost 20 hours out of every 24, conditions are more favorable to rapid drying of fuels than on the valley bottom. The altitude of least humidity at night is higher than the altitude of nightly maximum temperature.

3. During fifteen hours out of every 24, relative humidity at the 2300 feet elevation station was greater, hence more favorable to fire control, than it was at any hour at 4400 feet.

North slopes show practically the same differences between altitudes as are shown in figures 1-A and 1-B for south slopes. Air temperatures are very similar at the north and south slope stations, but relative humidity is generally 4 to 6 degrees higher on the northern aspects only 100 feet below the ridge top.

Fuel moisture

Variations in the moisture content of light fuels, which, on a typical August day, depend largely on temperature, humidity, and sunlight, are shown in figures 2-A and 2-B. As would be expected, these data for half-inch wood moisture and for duff moisture show practically the same zones and trends that the temperature and relative humidity charts show. They emphasize the occurrence of the greatest sustained danger in the intermediate altitudinal zone.

The present work has shown, however, that another factor, previously recognized as important by Gast and Stickel 1/, has a decided effect upon duff moisture. This is the heat generated by direct sunlight, at the surface of the duff layer. South facing duff beds receive the rays from the summer sun at an almost perpendicular angle; consequently, they experience a maximum of heating, and, as shown by figure 2-B, south slopes at all altitudes have about the same minimum daily moisture content. Horizontal and north facing duff beds receive the rays at a more oblique angle; consequently, they are heated less and remain one or two percent more moist each day. Half-inch wood cylinders, on the other hand, are all exposed horizontally and 10 inches above the ground; hence, are not subject to this difference in sun's angle on the north and south slopes. Consequently, they have practically the same minimum moisture content on both aspects but respond to temperature and humidity differences with altitude.

Wind

Summer winds in the study area are usually southwesterly; consequently, average wind velocity is stronger on south than on north slopes. Table 1 shows the various wind velocities at the several stations. At the level of 7½ feet above the ground or lower, the maximum velocity usually occurs between noon and 3:00 P.M. while the minimum usually occurs between midnight and 3:00 A.M., regardless of altitude.

Table 1.--Maximum, minimum, and average daily wind velocity at six inflammability stations on the median day of August, 1936. Anemometers 7½ feet above ground.

Wind Velocity	Altitude and Aspect							
	2700'		3800'		5500'		Average	
	North	South	North	South	North	South	North	South
	Miles per hour							
Maximum	1.8	5.1	1.0	5.8	4.5	6.4	2.4	5.8
Minimum	0.7	1.1	0.3	1.1	1.5	3.5	0.8	1.9
Daily	1.0	2.6	0.7	3.0	3.0	4.6	1.6	3.4

As shown by these data, there is a gradual increase in velocity with altitude, but at the height at which the anemometers were exposed, 7½ feet, the increase is not great. Wind movement at the 3800 north slope station does not show this increase, probably because of the greater density of the timber stand surrounding this station.

1/ Gast, P.R., and Stickel, P.W. Solar radiation and relative humidity in relation to duff moisture and forest fire hazard. Mo. Wea. Rev. 57:466-468, illus. 1929.

Fire behavior

Of all the variable factors of fire danger which influence fire behavior in any fuel type, fuel moisture and wind velocity are the two most important. These two factors combine to produce very significant differences in class of fire behavior by time of day, by altitudes, and by aspects. The fire behavior classes, computed by use of the Northern Rocky Mountain fire danger meter are shown in table 2.

Table 2.--Daily march of fire behavior on north and south slopes at elevations of 5500, 3800, and 2700 feet; and on a fully exposed and a partially timbered site at 2300 feet. Median day of August, 1936.

Station	Hour of Day												Ave.
	A.M.					Noon	P.M.					Mdnt	
	2	4	6	8	10		2	4	6	8	10		
	Fire Behavior Classes[1]												
2300'													
Partly Timbered	3	3	3	3	3	4	4	4	4	4	4	4	3.6
Fully Exposed	3	3	3	3	4	5	5	4	4	4	4	4	3.8
2700' North	3	3	3	3	3	4	4	4	4	4	3	3	3.4
South	4	4	4	4	4	5	6	6	4	4	4	4	4.5
3800' North	4	4	4	4	4	4	5	4	4	4	4	4	4.1
South	4	4	4	4	5	6	6	6	4	4	4	4	4.6
5500' North	4	4	4	4	4	5	5	5	4	4	4	4	4.2
South	4	4	4	4	5	6	6	6	5	4	4	4	4.7

1/ Computed according to directions on "B" slide of the Northern Rocky Mountain fire danger meter for determining the fire behavior usually associated with each danger class. This procedure eliminates visibility and lightning occurrence which have no bearing on fire behavior.

This table shows concisely certain outstanding facts that the fire dispatcher in Region One can use to improve his estimate of the number of men that should be sent to a fire.

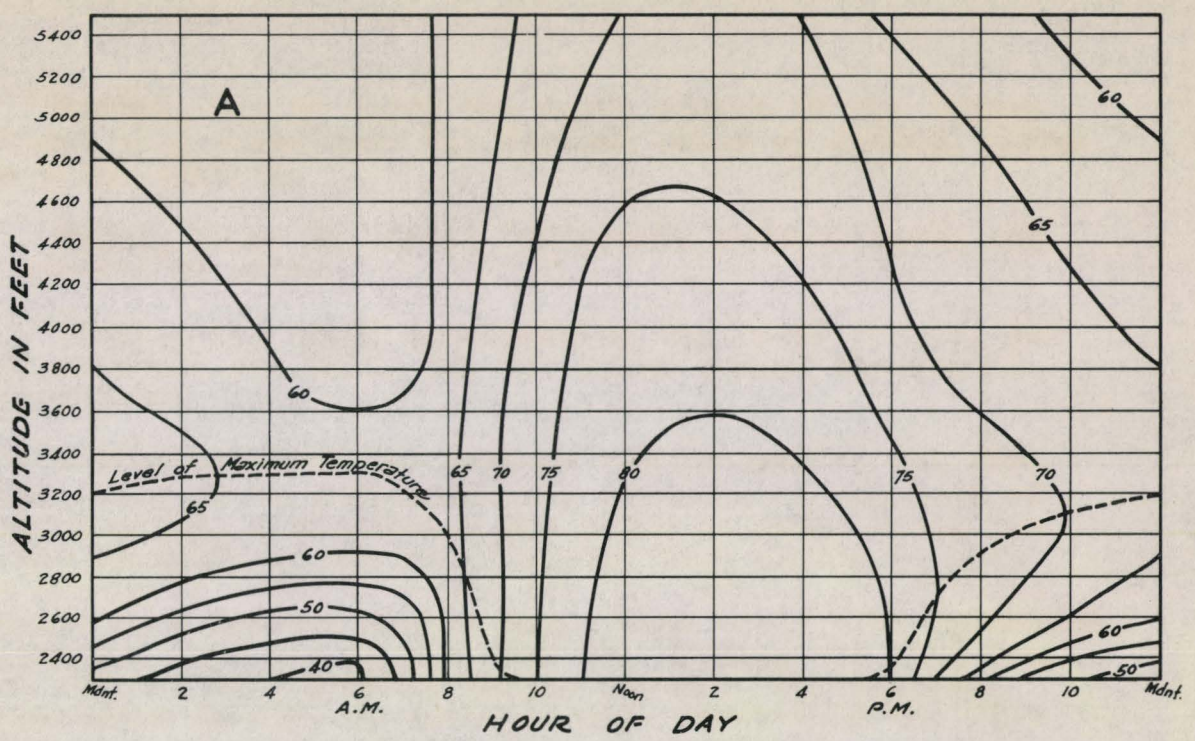
First, the daily pick-up in rate of spread commences between 8:00 and 10:00 A.M. on the south slopes at elevations of perhaps 3500 feet and higher. At lower elevations, and on all north slopes this pick-up commences between 10:00 A.M. and noon. The Forest Service "control by 10:00 A.M." general policy is therefore well selected.

Second, day or night the south slopes at the higher elevations will experience the fastest rates of spread, other things being similar.

Third, there is little difference between north and south aspects at night.

Fourth, the areas experiencing the least danger, due to fuel moisture and wind, are the north facing aspects at low elevations.

Having measured the factors and determined the fire behavior class at an inflammability station, at any hour of the day or night, a dispatcher may refer to table 2 and improve his estimate of the modification that should be made in his rating in order to allow for the effects of altitude and aspect on a typical August day. This table also indicates the allowance that may be made for the shading and wind reduction effects of a partial timber canopy. Furthermore, the dispatcher is able to estimate more accurately the fire behavior to be expected at the fire spot when his men will arrive there, perhaps several hours later, if the weather forecast indicates a normal, typical day.



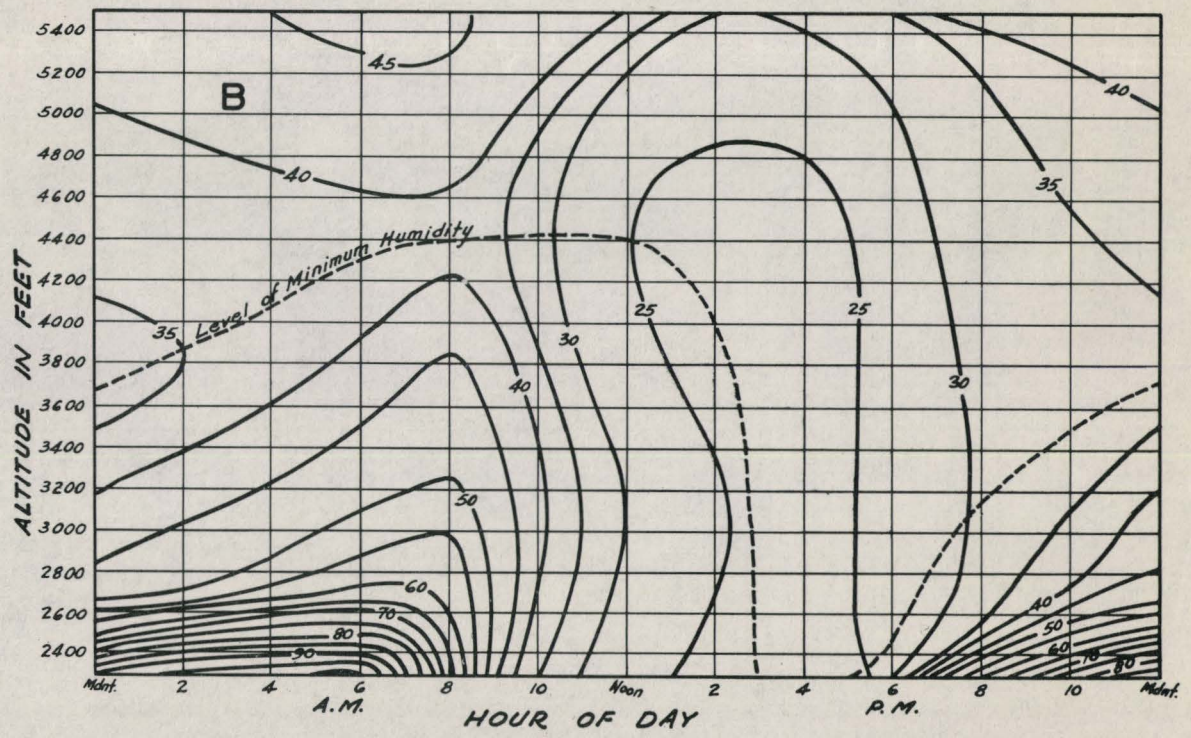
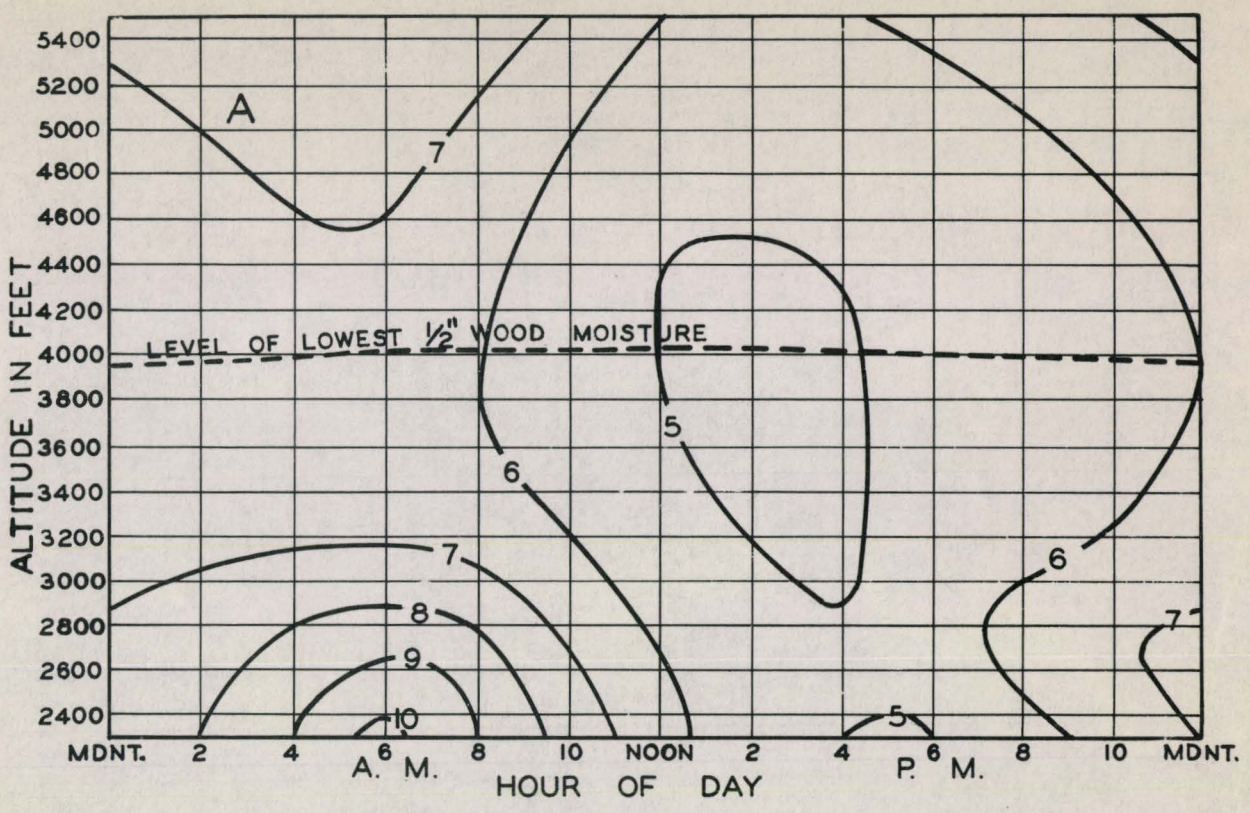


FIG. 1-A-ISOGRAMS OF TEMPERATURE ALONG SOUTH SLOPES
B-ISOGRAMS OF RELATIVE HUMIDITY ALONG SOUTH SLOPES
MEDIAN DAY OF AUGUST, 1936, ON PRIEST RIVER EXPERIMENTAL FOREST



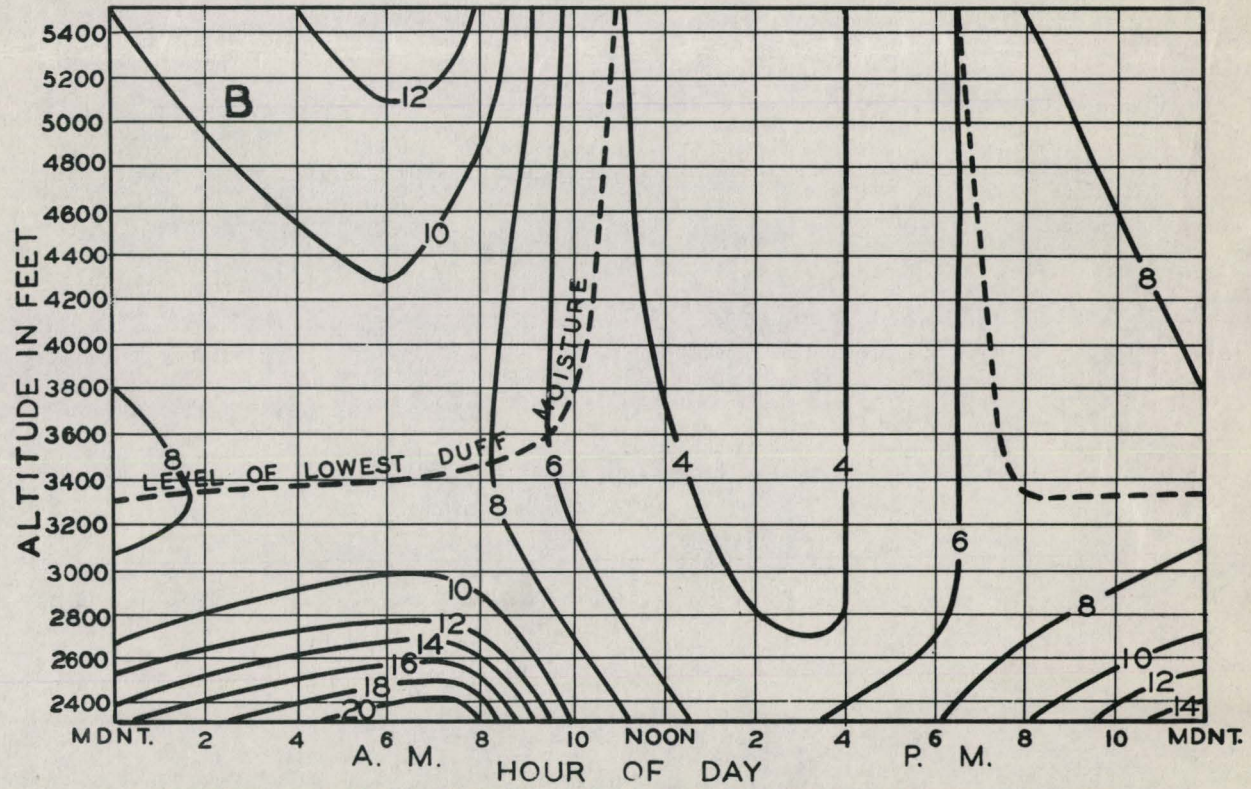


FIG. 2 -A-ISOGRAMS OF HALF-INCH WOOD MOISTURE ON SOUTH SLOPES
B-ISOGRAMS OF DUFF MOISTURE ON SOUTH SLOPES

MEDIAN DAY OF AUGUST, 1936, ON PRIEST RIVER EXPERIMENTAL FOREST